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The Hidden World Under Our Feet

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THE world's worrisome decline in biodiversity is well known. Some experts say we are well on our way toward the sixth great extinction and that by 2100 half of all the world's plant and animal species may disappear.

Yet one of the most important threats to biodiversity has received little attention — though it lies under our feet.

Scientists using new analytical techniques over the last decade have found that the world's ocean of soil is one of our largest reservoirs of biodiversity. It contains almost one-third of all living organisms, according to the European Union's Joint Research Center, but only about 1 percent of its micro-organisms have been identified, and the relationships among those myriad life-forms is poorly understood.

Soil is the foundation on which the house of terrestrial biodiversity is built. Without robust soil ecosystems, the world's food web would be in trouble.

To understand more, scientists recently embarked on what they call the Global Soil Biodiversity Initiative to assess what is known about soil life, pinpoint where it is endangered and determine the health of the essential ecosystem services that soil provides.

They are not just looking at soil in remote, far-off landscapes. One of the more intensive studies is taking place in New York's Central Park.

The focus is on the life that resides in the soil — the microbes, fungi, nematodes, mites and even gophers that make up a complex web of interrelationships.

A teaspoon of soil may have billions of microbes divided among 5,000 different types, thousands of species of fungi and protozoa, nematodes, mites and a couple of termite species. How these and other pieces all fit together is still largely a mystery.

"There's a teeming organization below ground, a factory, with soil animals and microbes, each with their own role," said Diana H. Wall, a professor of biology at Colorado State University who has studied soil biodiversity in Antarctica and Kansas over the last two decades and who is the scientific chairwoman of the soil biodiversity initiative. "A leaf falls, and earthworms and termites are constantly ripping and tearing it apart, and microbes and fungi pass the nutrients on to plants."

Forget the term "dumb as dirt." The complex soil ecosystem is highly evolved and sophisticated. It processes organic waste into soil. It filters and cleans much of the water we drink and the air we breathe by retaining dust and pathogens. It plays a large role in how much carbon dioxide is in the atmosphere. Soil, with all of its organic matter, is second to the oceans as the largest carbon repository on the planet. Annual plowing, erosion and other mismanagement releases carbon in the form of carbon dioxide, and exacerbates climate change.

The last decade of research has overturned a key concept. For decades there was a saying among soil scientists — "everything is everywhere," which meant that soil was largely the same across the globe. That has proved to be spectacularly untrue.

A 2003 study in the journal Ecosystems estimated that the biodiversity of nearly 5 percent of the nation's soil was "in danger of substantial loss, or complete extinction, due to agriculture and urbanization," though that was most likely a very conservative guess, since the planet's soil was even more unexplored then than today, and study techniques were far less developed.

That means that species critical to some important functions could have already disappeared or be on their way out. That's why the global soil assessment is a matter of some urgency.

There are numerous threats to soil life. Modern tillage agriculture is a big one, because it deprives soil life of organic matter it needs for food, allows it to dry out and adds pesticides, herbicides and synthetic nitrogen. Soil "sealing" from the asphalt and concrete of suburban sprawl destroys soil life, as do heavy machinery and pollution. Even long-ago insults like acid rain still take a toll on life in the soil by having made the soil more acidic.

THE problem is global. In nearly half of Africa, for example, overgrazing and intensive agriculture has destroyed topsoil and led to desertification.

Yet few things are more vital than healthy soil life. Our food supply begins in the soil. Wild plants need healthy soil to grow well, so other species can eat the leaves and seeds and fruit, and predators can eat the plant eaters.

Healthy soil can prevent human disease. Valley fever is found in the southwest United States and is caused by a fungus that becomes airborne when soil dries out and is inhaled. It is rapidly increasing. The soil system also plays what is thought to be a key, if poorly understood, role in the spread of cholera, fungal meningitis and other diseases, which live part of their life cycle in the soil.

Healthy soils also hold the cure for some diseases. Antibiotic compounds are the chemical weapons of competing soil microbes, and most of the antibiotics we use came from there. Scientists are searching soil in various places now for a new class of antibiotics to deal with antibiotic-resistant diseases. Who knows, the answer may lie underneath the fountains and sidewalks of Central Park.

New technologies that enable scientists to study the genes of soil microbes and to track microscopic amounts of carbon and nitrogen as they pass through the soil ecosystem have provided leaps in the understanding of soil ecology. But the more scientists learn, the more they realize how little they know.

Global warming will no doubt greatly compound the threats to soil biodiversity. Food security is a big concern. What will happen to crops as the earth gets warmer? Slight changes in temperatures and moisture can have profound impacts on soil, altering the composition of soil life and the types of plants that will grow. We may no longer be able, for example, to grow wheat in Kansas.

Some plants are expected to gradually migrate north to cooler climates as it warms, but others may not be able to adapt to new soil communities. "The world above ground and the world below are very tightly linked," said Dr. Wall.

Scientists are also discovering that a healthy soil ecosystem may sustain plants naturally, without chemical inputs. "The greater the soil diversity, the fewer diseases that emerge in plants," said Eric B. Nelson, who studies soil and disease ecology at Cornell. Insects are also deterred by plants grown in healthy soils, he said.

What can farmers and gardeners do to protect their soils? Practice no-till agriculture for one, Dr. Wall said, which means not plowing every year and allowing dead vegetation to decompose. Backyard gardeners can do the same. Avoiding synthetic chemicals is also important. Adding compost, especially worm compost, can help by making soil ecosystems more robust.

The topic is starting to get the attention it deserves. Dr. Wall was just awarded the Tyler Prize for Environmental Achievement, a distinguished prize that comes with $200,000 that she says plans to use for her research. "It's showtime for soil biodiversity," Dr. Wall said.

Jim Robbins is a frequent contributor to the Science section of The New York Times and the author of "The Man Who Planted Trees."

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